

PRECISION FISH FARMING IN NIGERIA: CHALLENGES AND OPPORTUNITIES

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Abstract

The use of modern technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Machine Learning in Agriculture has revolutionized agricultural practices and productivity. Precision Fish Farming (PFF) is the use of technology and automation in aquaculture to improve the accuracy and repeatability of fish farming operations thereby enhancing productivity, environmental sustainability, and overall fish health and welfare. This paper examines the application of PFF tools among fish farmers in Delta State, Nigeria, focusing on their challenges and potential solutions. Using Google Forms distributed via WhatsApp, 201 fish farmers were surveyed to evaluate their knowledge, degree of acceptance, and limitations in using PFF technology. Descriptive analysis tools such as frequency, percentages, pie charts, and bar charts were used for visualization of the result as well as a Pareto chart to show the causes of non-adoption of precision fish farming tools by the fish farmers in the study area. Our findings revealed that while 55.72% of farmers are aware of PFF tools, only 33.33% have implemented water quality monitoring sensors, with no adoption of automated feeding systems or fish health monitoring tools. High costs (22.22%), lack of knowledge (33.33%), and limited access to technology (55.72%) were identified as major barriers to adoption. To improve the use PFF tools among Nigerian fish farmers, the researchers advise infrastructural expansion such as providing stable electricity and internet access, financial aid, and regular training.

Keywords: Precision fish farming, Automated Fishing, Nigeria Fish farmers, Aquaculture

Introduction

In Nigeria, aquaculture plays a crucial role in ensuring food security, creating jobs, and fostering economic development. With the right assistance, the sector might surpass the oil sector in terms of Gross Domestic Product (GDP) (Ikenga *et al.*, 2023; Ogunremi and Olatunji, 2019; Omotesho *et al.*, 2019). Despite this potential, Nigeria faces a fish supply deficit of approximately 2.5 million metric tons annually (Okeleji, 2024). This necessitates the adoption of contemporary technology to bridge the gap and enhance productivity.

Using cutting-edge technology like Artificial Intelligence (AI), the Internet of Things (IoT), and Machine Learning to

maximize fish output, Precision Fish Farming (PFF) presents an inventive answer to increasing productivity and safety (Rowan, 2023; Zhang and Gui, 2023). Precision farming in fish production is geared toward applying engineering ethics in fish production, thereby improving the farmer's skill to control, monitor closely, and document biological processes in fish farms (Bolaji *et al.*, 2020). The benefits of adopting this innovative technology for enhancing fish production stirred this study which aims to investigate the use of PFF tools among fish farmers in Delta State, identifying the challenges and opportunities to their adoption and proffer possible remedies. The objectives of this study are to design survey questions using Google

Forms, collect information from registered fish farmers in Delta State via their WhatsApp platform, analyzing the collected data using descriptive tools.

Using control-engineering ideas, PFF enhances monitoring, control, and documentation of biological processes of fish production. Fish health, production, and environmental sustainability are improved by this change from experience-based to knowledge-based fish farming (Zhang and Gui, 2023). Key principles of PFF include: controlled feeding systems for precise nutrition management; Automated monitoring of fish health and behavior, Adaptation to complex underwater farming environments and addressing external stressors such as pathogens, pollutants, and climate change.(Bachri, 2023; Bapu *et al.*, 2023; Bolaji *et al.*, 2020). Using automation, PFF may help fish farming enterprises to increase their accuracy, efficiency, and decision-making capacity. PFF tools operate via four main phases namely Observation, Interpretation, Decision, and Act phases (Agossou and Toshiro, 2021). Traditional monitoring of fish bio-responses through manual observation, is subjected to erroneous decisions due to human inadequacy. PFF introduces advanced tools such as: Submerged Cameras and Computer Vision which are used for tracking fish behavior, clustering, size estimation, and disease detection (Karningsih *et al.*, 2021; O'Donncha and Grant, 2019). Hydroacoustic Devices (Echo Sounders) analyze fish dispersion and schooling density to help in feeding and fish health (Vaught, 2024; Bachri, 2023). Fish farmers often interpret observations based on experience, however, modern approaches include: Mathematical modeling and AI which predict fish growth and behavior based on environmental and biological factors (Føre *et al.*, 2017; Dumas *et al.*, 2010). AI-driven detection identifies unusual fish activity, indicating disease or environmental stress(Omede and Okpeki,

2023). With the integration of automated data, Decision Support System (DSS) enhances decision-making. In Feeding Optimization, AI-based systems determine optimal feeding schedules and quantities, reducing waste and improving fish growth unlike in manual feeding fish can be overfed or underfed. The irregularities in feeding can create an unhealthy environment which can cause fish dead or retard growth. PFF tools for environmental Monitoring detect harmful substances before they affect fish health (Dhinakaran, 2023; Rowan, 2023; Rowan, 2023 Janpla *et al.*, 2019). In Indonesia for instance, IoT-based monitoring systems optimize shrimp pond conditions while in Norway, AI-powered cameras and underwater drones monitor fish health (Fore *et al.*, 2018). Automation reduces labor costs and enhances efficiency: Autonomous Feeding Systems convert AI-based feeding decisions into precise actions, improving overall fish health and productivity (Bachri, 2023; Eneh *et al.*, 2023; Karningsih *et al.*, 2021). Assist with underwater maintenance, fish health checks, and net cleaning using Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) (Duda *et al.*, 2015). Fish health checks, and net cleaning (Føre *et al.*, 2017; Duda *et al.*, 2015). For instance, in Florida (USA), the Atlantic Sapphire salmon farm uses advanced Recirculating Aquaculture System (RAS) technology for precision monitoring (AHSN, 2021). Monitoring of fish health with IoT-based tools(Ajoge *et al.*, 2023; Agossou and Toshiro, 2021; Gao *et al.*, 2019). From the literature, it has been observed that Precision techniques minimize waste and promote sustainability thereby reducing environmental impact on fish productivity. Automations reduce labour and input expenses lowering operational costs and thus increasing profitability(Karningsih *et al.*, 2021; Fore *et al.*, 2018).Several studies have examined Nigeria's readiness to embrace precision fish farming. Many farmers struggle to comprehend and utilize modern fish

farming information effectively, limiting productivity (Aremu *et al.*, 2024). A study in Rivers State found that while 91.4% of fish farmers were aware of modern technologies, only 21% adopted them due to high costs, lack of capital, and unreliable power supply (Ogunremi and Olatunji, 2019). In Oyo state research by (Akinbile and Alabi, 2010) on the use of ICTs among fish farmers revealed that the behaviour of fish farmers to information is not poor but they lack enough knowledge of ICTs especially modern tools and potentials embedded therein for the productivity and increase in fish farming. Aphunu and Atoma (2013) examined the use of ICT tools for information dissemination among fish farmers in Delta State and observed that most small-scale fish farmers rely on mobile phones, radio, and television for their information. Nevertheless, the limitation of rural poverty and inadequate training hinder the general implementation of information and communication technologies-based agricultural solutions. In Omotesho *et al.*, (2019), the researchers analyzed the use of ICTs in fish farming in Kwara State, Nigeria, their findings revealed that the use of ICTs in fish farming in the state was low despite the high level of awareness, this is also in line with research in Rivers state Nigeria by (Ogunremi and Olatunji, 2019) in adoption of precision tools by fish farmers in the state. With Delta State as the case study, this study aims to identify the limitations restricting the capacity of fish farmers to adopt innovative technology particularly precision tools in their farming activities. (Onyeacholem and Omede, 2023)

Material and Methods

The Study area

This study was carried out in Delta State, Nigeria. The state was created from the former Bendel state on 27th August 1991. It is in the Southern part of Nigeria and lies roughly between longitude 5.0° and 6.45° East and Latitude 5.0° and 6.3° North. Delta

state is bounded on the North by Edo State, and on the East by Anambra and Rivers States. The Western boundary is formed by the Atlantic Ocean while the North East boundary is Ondo state. The state has a total landmass of 17,108 km² and a population of over 6,037,667.

Sampling/selection Procedure and Sample Size

The study adopted multi-stage sampling technique involving three stages as expressed below;

Stage 1: Stratifying Delta State into three Senatorial/Agricultural zones.

Stage 2: Randomly selecting eight Local Government Areas (LGA) from the three senatorial zones.

Stage 3: Randomly selecting one community each from the LGA.

In the first stage, the state was stratified into the three geopolitical/agricultural zones; Delta Central, Delta North and Delta South. The stratification is to enable a perfect representation of the fish farmers in all parts of the state. In the second stage, four (4) LGAs; Bomadi, Burutu, Isoko North and Warri South, were selected from Delta South. Delta south communities are mostly riverine communities with major occupation, fishing. Although, the study is not focusing on fishing from the natural source (rivers) but given that these areas are known for fishing as a primary occupation, other methods of fish farming (pond, tank, etc) are predominant in these region. Two (2) LGAs each were selected from from Delta Central; Ughelli North and Ethiope East and Delta North; Ndokwa East and Oshimili South, for fair representation. For the third stage, one community each was selected from each LGA, making a total of eight (8) communities. These communities were selected based on their level of development i.e urban and rural. Asaba, Ozoro, Ughelli, Warri are the urban areas

while Abraka, Bomadi, Burutu and Aboh are the rural communities. Again, a total of 225 fish farmers were randomly selected from these communities. 40 respondents each were selected from the urban communities while 16 respondents were selected from the rural communities except Abraka where 17 respondents were used. The information about the fish farmers were elicited from Catfish Farmers Association, a registered association with the Ministry of Agriculture and Natural Resources, Delta State, Nigeria.

Data Collection

Data was collected using structured questionnaire. The design of the structured questionnaire was a combination of closed and open-ended questions. Data collection was done through an online survey using the Google survey tool. The questionnaire was structured in four sections; section A was used to gather demographic data using the variables: age, gender, educational background, and farm location. Section B was used to gather fish farming practices using variables: years of experience in fish farming, major type of fish being farmed, size of fish farm, type of fish farm, and frequency of water monitoring. Section C was used to gather information on technology adoption using these variables; Precision Fish farming (PFF) Technology awareness, PFF technologies implemented, problems for non-implementation of the

technologies, and possible solutions. Finally, section D was on Challenges and desired opportunities by the respondents.

Validation of Survey Instrument (Interview Questionnaire)

The questionnaire was validated by the experts in the fields of agriculture and Information and Communication Technology (ICT). To ensure the reliability of the questionnaire, a pre-test was conducted by taking a random sample of 15 fish farmers in Obiaruku (rural) and Kwale (urban). These two communities are not part of the main study area. The results helped to revise the instruments, ensuring efficiency and reliability.

Data Analysis

The data gathering was done for the period of three months from September 2024 to November 2024. Out of 225 questionnaires distributed, only 201 persons responded, approximately 89% of the total population spread across the three agricultural zones in Delta State. The retrieved data through the Google form was analysed using descriptive statistics, such as frequency, mean, standard deviation, chart, cross-tabulation. Pareto chart was also used to show the causes of the non-adoption of PFF tools by the fish farmers in the study area.

Results and Discussion

Table 1: Summary of data collected on the demographic characteristics of the respondents

Variables	Frequency	Percentage (%)	Mean
Age			
<20	0	0	
20-29	22	10.95	
30-39	45	22.39	43.89
40-49	67	33.33	
>=50	67	33.33	
Gender			
Male	134	66.7	
female	67	33.3	
Educational Background			
Tertiary	161	80	

Secondary	0	0
Primary	0	0
Others	40	20
Farm Location		
Urban	156	77.8
Rural	45	22.2

The age distribution shown in Table 1 depicts that the majority of the respondents are between the ages of 40 to 50 years in agreement with (Aphunu and Atoma, 2013; Aremu *et al.*, 2024). This implies that the respondents are middle-aged and older, which may affect the adoption of technology due to generational differences in familiarity with modern tools. However, being matured, they need technological assistance to reduce working stress and improve production.

Also from Table1, the greater percentage (67%) of the respondents are male still in consonance with (Aremu *et al.*, 2024; Oyibo, 2021; Aphunu and Atoma, 2013) . This implies that more male is involved in fish farming in the study area. Labour intensiveness and time consumption

involve in fish farming activities may be the reason women are scared to venture into the business, but with the awareness and use of precision tools, women may be encouraged to participate actively in the fish farming business.

A significant majority (80%) of farmers have tertiary education, while 20% fall into "Other" categories, with no representation from primary or secondary levels as is depicted in Table 1. An advanced degree helps improve understanding and use of precision tools. About 78% of the participants have their farms in urban areas. This implies that the difficulty of non-operational surroundings for these tools does not apply to the respondents.

Fish Farming Practice

Table 2: Fish Farming Practice

Variables	Frequency	Percentage (%)
Years of experience		
4 – 6 years	67	33.33
7 - 10 years	89	44.28
>10years	45	22.39
Major type of fish beina		
Catfish	201	100%
Tilapia fish	45	22.22
Carp	0	0
Others	0	0
Size of Fish farm		
Small scale(<1000 fish)	45	22.39
Medium (1000 -5000)	67	33.33
Large (>5000)	89	44.28
Type of fish farm		
Pond system	89	44.28
Tank system	89	44.28
Cage system	0	0.00
Others	23	11.44
Frequency of water quality monitoring (parameters: pH, Temperature, and		
Daily	23	11.44
Weekly	44	21.89
Monthly	89	44.28
Rarely	45	22.22
Never	0	0.00

Table 2 summaries the data collected from the respondents using different fish farming practice variables. The variables are *Years of experience*

visualized using pie and bar charts as are shown in Figures 2a to 2e.

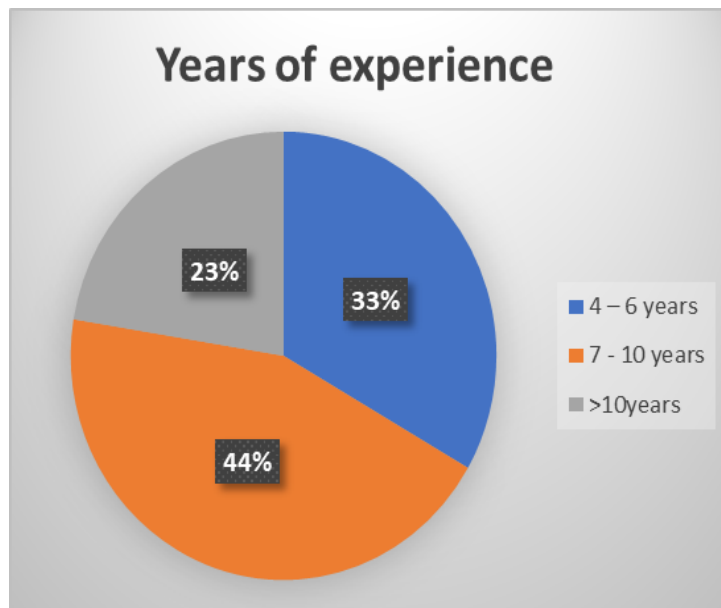


Figure 2a: Visualization of Years of experience using pie chart.

Figures 2a shows that the majority of the respondents (44%) have at least 7 to 10 years of experience in the fish farming business, 33% have between 4-6years experience and 23% only have 10 and above years of experience. The implication is that majority of the respondents were not so much experienced in fish farming
Major type of being farmed

practice, so there is need for farmers to be trained to adopt the new technologies effectively while experience farmers who have encountered challenges like poor water quality, disease outbreaks and inconsistent fish growth rate are more likely to appreciate the benefits of precision tools.

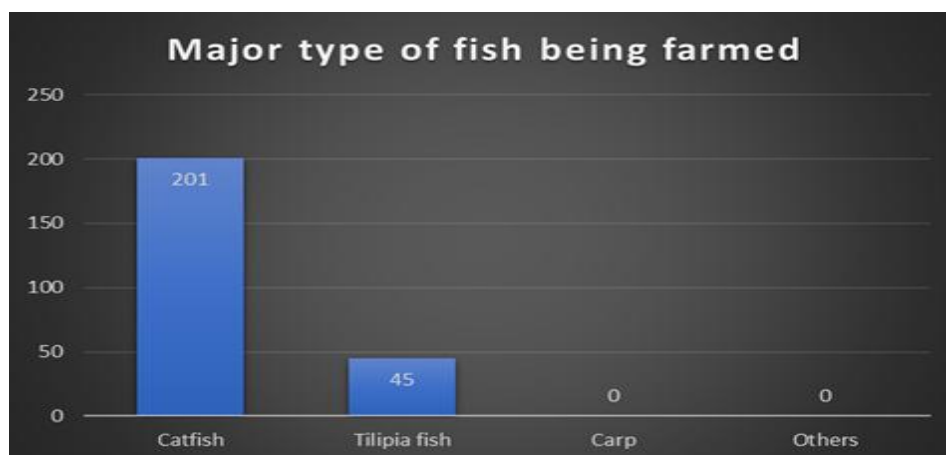
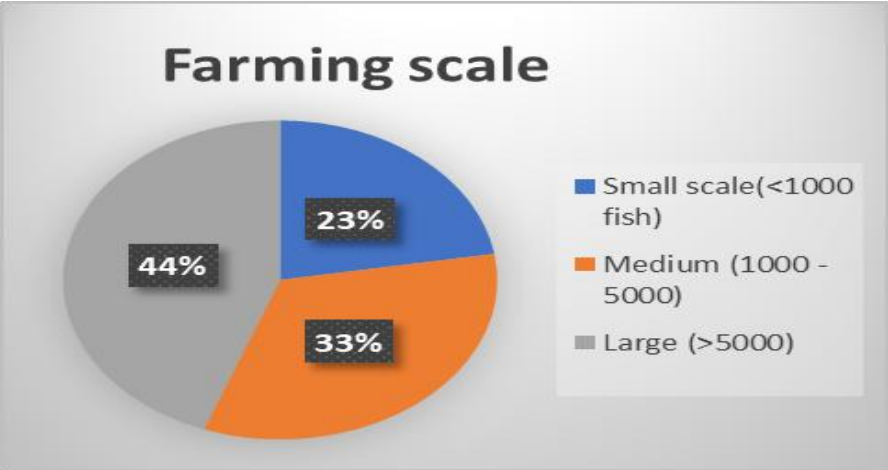


Figure 2b: Visualization of major type of fish farmed using bar chart

Figure2b shows that all the respondents (100%) rear Catfish with 22.22% also farm Tilapia, and none rear carp or others. Catfish farming, being dominant in Nigeria as confirmed with (Aremu *et al.*, 2024;

from precision tools that optimize feeding, monitor oxygen levels, and prevent overstocking. Automated feeding systems and water quality sensors can improve growth rates and reduce death rate.



Ogunremi and Olatunji, 2019) can benefit

Size of pond

Figure 2c: Size of the farm

Figures 2c shows the scale farm, that is the farm size. The largest population of the respondents (44%) operate large farms (>5,000 fish). This implies that the use of precision tools like IoT-based sensors,

automated feeder and water quality monitoring system is required to enhance efficiency, reduce labor costs, and monitor fish health at scale. Smaller farms might be hesitant due to cost, but affordable and scalable solutions could encourage adoption.

Type of pond.

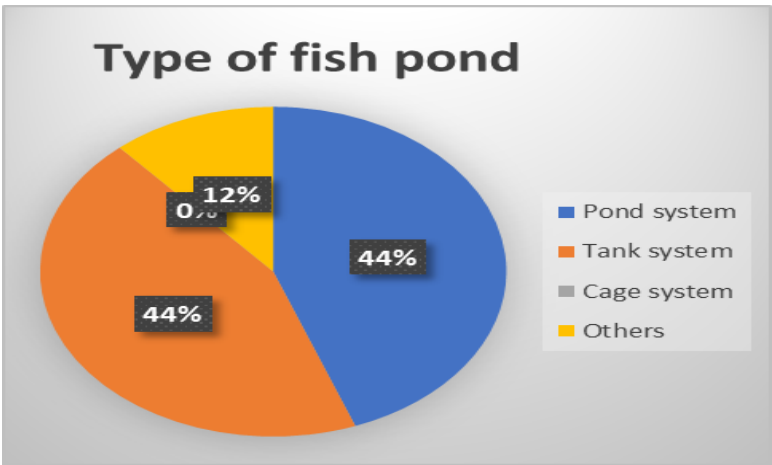


Figure 2d: Type of pond

An equal number of farmers (44%) use pond and tank systems, while 12% use

other methods as is depicted in Figure2d. Pond and tank systems can benefit from

automated aerators, real-time water quality monitoring, and smart feeding system

Water monitoring frequency

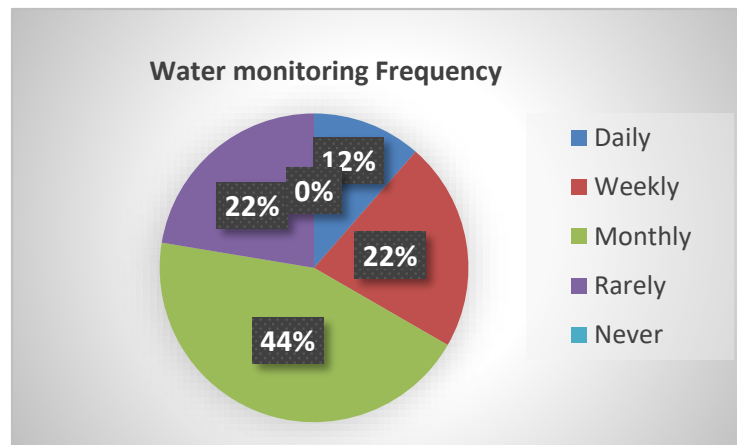


Figure 2e: Water quality monitoring Frequency

Figure 2e shows that only 12% of farmers monitor water quality daily, while 44% do so monthly, and 22% weekly and other 22% rarely check it. Water quality is critical for fish health. The fact that only 12% do daily monitoring suggests a major gap where precision tools, like automated sensors, can provide real-time data and alerts. Also, the

44% who check monthly are at risk of missing sudden changes in pH, temperature, or oxygen levels, which could lead to fish mortality. Precision farming tools can help reduce losses by ensuring timely interventions.

Technology Adoption

Table 3: Technology Adoption

Variable	Frequency	Percentage (%)
Precision Technology Awareness		
Yes(1)	112	55.72
No(0)	89	44.28
Technologies implemented		
Water Quality	67	33.33
Automated feeding	0	0
Fish health monitoring	0	0
Data analysis software	22	10.95
None	112	55.72
Reasons for non-implementation of Technology		
High cost	45	22.22
Lack of knowledge	67	33.33
Lack of access to	112	55.72
	22	10.94
Others	22	10.94
Interest in adopting the technologies if given the opportunity		
Yes	201	100
No	0	0

Needed Support		
Financial Assistance	178	88.8
Training	112	55.6
Technical Support	45	22.2
Access to the internet and power	45	22,2
others	0	0

Table 3 summarizes the data collection on technology adoption using variables like *Precision Technology awareness, Technologies implemented, Reasons for non-implementation of technology, Interest*

in adopting the technologies, and needed support. In addition to pie and bar charts used in visualizing the data, a Pareto chart was used to show the major cause of non-implementation of the technologies.

Precision Technology Awareness

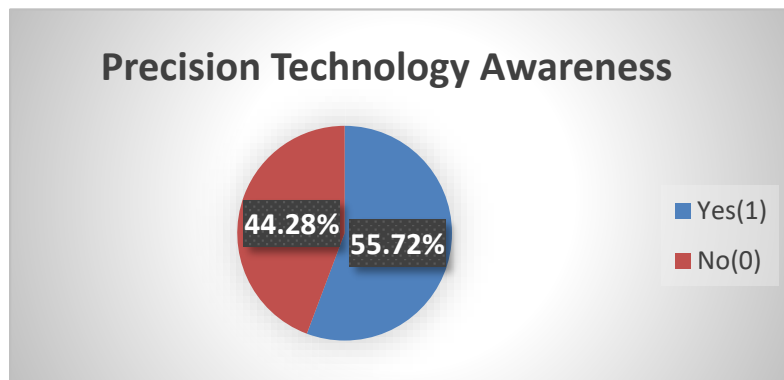


Figure3a: Precision Technology Awareness

A significant number of the respondents (55.72%) are aware of precision technology tools, while 44.28% are not which agrees with (Ogunremi and Olatunji, 2019) in which 75.8% of fish farmers in their

research are aware of one type of Precision tool or the other which shows that the lack of awareness of these technologies is not among the reasons of their non-implementation in fish farming.

Technologies Implemented

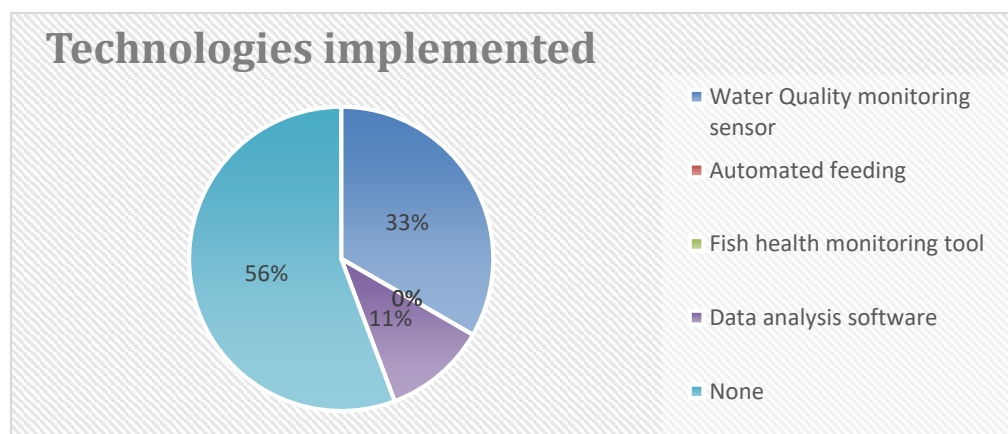


Figure 3b: Technologies implemented

Despite the greater percentage of awareness, it can be seen from Figure 3b that the greatest percentage of the respondents (56%) has not adopted any of the technologies, 33% adopted Water quality

monitoring sensors, 11% adopted data analysis software, fish health monitoring tool, and automated feeding were not adopted by any of the respondents.

Barriers to Adoption Precision tools in fish farming

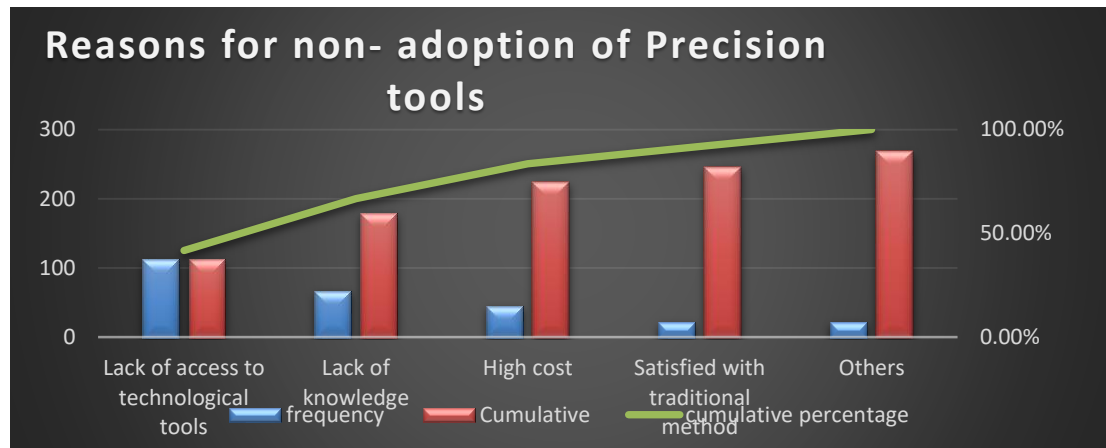


Figure 3c: Pareto chart for the causes of non-adoption of precision tools by respondents

Table 3 reveals that while Nigerian fish farmers show interest in adopting precision farming tools, barriers like lack of access, limited knowledge, and high costs, as is depicted by the Pareto chart in Figure 3c prevent widespread adoption. Addressing these challenges with financial, educational, and infrastructural support can significantly improve productivity and sustainability in the sector.

Needed Support for adoption of PFF tools

Figure 3d shows that the greatest percentage of the fish farmers (88.9%) indicated their need for financial assistance either in form of loan or subsidies to enable them adopt the use of precision tools. Another major request is training on use of these tools which is indicated by 55.6%.

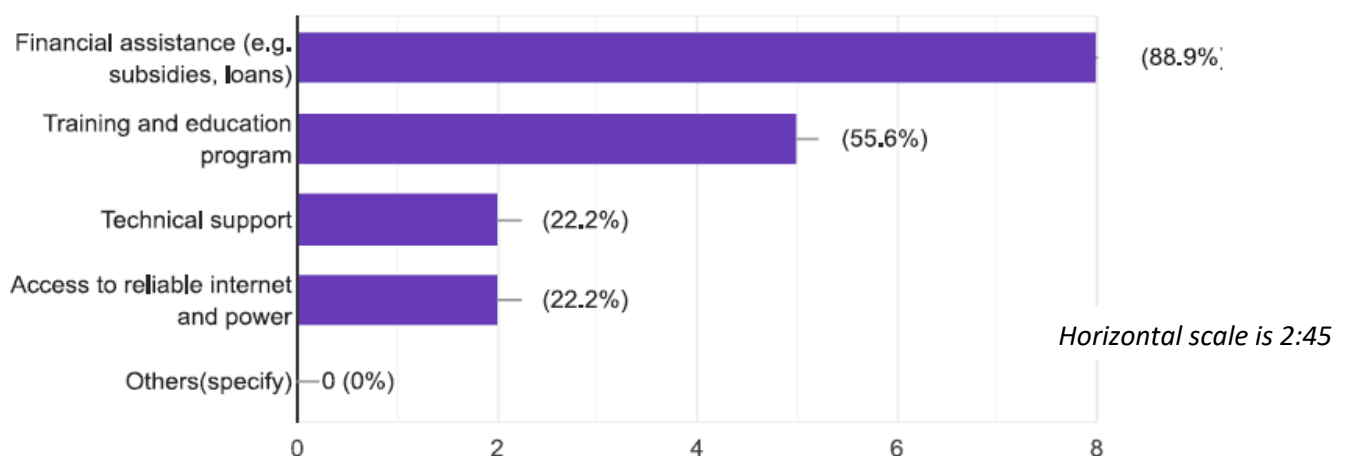


Figure 3d: Needed supports by the respondents

Table 4: Challenges in Fish Farming Operations

Variables	Frequency	Percentage (%)
High cost of feed	201	100
Water quality management	22	10.94
Disease outbreak	89	44.27
Market inaccessibility	45	22.38
Lack of technology	67	33.33

Table 4 shows that the most challenging factor reported is high cost of feeding, which is an economic burden on the farmers, the adoption of PFF tools will ensure proper management of fish feeding reducing unnecessary waste, overfeeding or underfeeding that retard productivity and growth. Another high operational issue that affected productivity is disease outbreak; this can be handled by automated water quality monitoring that ensures balanced and hygienic aquatic environment.

Conclusion

Precision Fish Farming is the use of technologies to monitor fish farming practices for optimum production. It has the potential to transform Nigeria's aquaculture industry by increasing productivity, reducing operational costs, and improving fish health. Through the use of multi-stage sampling technique, this study seek to find the extent to which fish farmers in Delta State, Nigeria has adopted the precision fish farming tool. The findings reveals that the adoption of these technologies is hindered by high costs, lack of awareness, poor infrastructure, and policy gaps. Addressing these challenges through government support, training, partnerships, and innovative technology solutions will pave the way for Nigeria's more sustainable and profitable fish farming sector. Government regulations and alliances with commercial technology companies may help to reduce costs and increase accessibility. Nigerian fish farming might see noticeably higher degrees of operational efficiency, profitability, and sustainability if identified challenges are properly addressed to enable

them adopt the use of PFF tools in their fish production.

Recommendation

We recommend infrastructural expansion such as providing stable electricity and internet access, financial aid, and regular training.

References

- Agossou, B. E. and Toshiro, T. (2021). IoT andamp; AI Based System for Fish Farming. *Proceedings of the Conference on Information Technology for Social Good, October*, 259–264.
<https://doi.org/10.1145/3462203.3475873>
- AHSN. (2021). Impact Report 20-21. In *The Academic Health Science Network AHSN*.
https://energypedia.info/wiki/EnDev_Report_on_Impacts
- Ajoge, N. S., Ahmed, M. A. and Balarabe, A. (2023). A Framework for an AI-IoT Based System for Improving Fish Production in a Smart Pond. *International Journal of Innovative Science and Research Technology*, 8(10), 1638–1643.
- Akinbile, L. A. and Alabi, O. E. (2010). Use of ICTs among fish farmers in Oyo state. *Journal of Agricultural Extension*, 14(1), 22–30.
- Aphunu, A. and Atoma, C. (2013). Extent of Use of ICTs by Fish Farmers in Isoko Agricultural Zone of Delta State,

- Nigeria. *Journal of Agricultural Extension*, 15(1), 10–21.
<https://doi.org/10.4314/jae.v15i1.2>
- Aremu, P. ., Akinboye, O. and Adewale, G. . (2024). Effect of Information Utilization on Fish Farmers' Level of Production in Abeokuta North Local Government Area, Ogun State, Nigeria. *Innovare Journal of Agricultural Sciences*, 12(2), 8–15.
<https://doi.org/10.22159/ijags.2024v12i2.49233>
- Bachri, A. (2023). Freshwater Monitoring System Design In Real-Time For Fish Cultivation. *International Journal of Multidisciplinary Approach Research and Science*, 2(01), 362–371.
<https://doi.org/10.59653/ijmars.v2i01.483>
- Bapu, P., Kumar, K. A., Rakesh, N., and Ramana, C. (2023). Development of Automatic Fish Feeding Machine for Integrated Floating Cage Aquageoponic System. *International Journal of Environment and Climate Change*, 13(3), 17–25.
<https://doi.org/10.9734/ijecc/2023/v13i31675>
- Bolaji, A. B., Olalekan, A. W. and Olanrewaju, O. E. (2020). Precision Farming Model for Optimum Catfish Production. *American Journal of Electrical and Electronic Engineering* 8(2), 51–59.
<https://doi.org/10.12691/ajeec-8-2-2>
- Dhinakaran, E. al. (2023). IoT-Based Environmental Control System for Fish Farms with Sensor Integration and Machine Learning Decision Support. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(10), 203–217.
<https://doi.org/10.17762/ijritcc.v11i10.8482>
- Duda, A., Schwendner, J., Stahl, A., and Rundtop, P. (2015). *Visual pose estimation for autonomous inspection of fish pens*. 1–6.
<https://doi.org/10.1109/OCEANS-Genova.2015.7271392>
- Dumas, A., France, J., and Bureau, D. (2010). Modelling growth and body composition in fish nutrition: where have we been and where are we going? *Aquaculture Research*, 41(2), 161–181.
<https://doi.org/10.1111/j.1365-2109.2009.02323.x>
- Eneh, A. H., Udanor, C. N., Ossai, N. I., Aneke, S. O., Ugwoke, P. O., Obayi, A. A., Ugwuishiwu, C. H., and Okereke, G. E. (2023). Towards an improved internet of things sensors data quality for a smart aquaponics system yield prediction. *MethodsX*, 11(October), 102436.
<https://doi.org/10.1016/j.mex.2023.102436>
- Føre, M., Frank, K., Norton, T., and Svendsen, E. (2017). Precision fish farming : A new framework to improve production in aquaculture ScienceDirect Special Issue : Engineering Advances in Precision Livestock Farming Precision fish farming : A new framework to improve production in aquaculture. *Biosystems Engineering*, 173(November 2019), 176–193.
<https://doi.org/10.1016/j.biosystemseng.2017.10.014>
- Gao, G., Xiao, K., and Chen, M. (2019). An intelligent IoT-based control and traceability system to forecast and maintain water quality in fresh fish farms. *Computers and Electronics in Agriculture*, 166(November), 1–9.
<https://doi.org/10.1016/j.compag.2019.105013>
- : Ikenga, V. U., Ogisi, O.D. and Gbigbi, T. M. (2023). Profitability of Aquaculture by Gender in Delta State, Nigeria. *Direct Res. J. Agric. Food Sci* 11(6), Pp.144-152.
<https://doi.org/10.26765/DRJAFS15212970>

- Janpla, S., Tachpetpaiboon, N., and Jewpanich, C. (2019). Development of Automatic Home-Based Fish Farming using the Internet of Things. *International Journal of Recent Technology and Engineering (IJRTE)*, 8(2), 3308–3315.
<https://doi.org/10.35940/ijrte.B2677.078219>
- Karningsih, P. D., Kusumawardani, R., Syahroni, N., Mulyadi, Y., and Saad, M. S. B. M. (2021). Automated fish feeding system for an offshore aquaculture unit. *IOP Conference Series: Materials Science and Engineering*, 1072(1), 012073.
<https://doi.org/10.1088/1757-899X/1072/1/012073>
- O'Donncha, F., and Grant, J. (2019). Precision Aquaculture. *IEEE Internet of Things Magazine*, 2(4), 26–30.
<https://doi.org/10.1109/IOTM.0001.1900033>
- Ogunremi, J. ., and Olatunji, S. . (2019). Constraints to adoption of fish farming technologies among fish farmers in Obio/Akpor Local Government Area of Rivers State, Nigeria. *Nigerian Journal of Animal Production*, 46(1), 256–262.
- Okeleji, S. (2024, June 24). *Staying Afloat in Fish Farming amid Rising input cost*.
<https://www.thisdaylive.com>
- Omede, E. ., and Okpeki, U. K. (2023). Use of Mathematical and Unified Modelling Language Tools to Provide Learning Motivation System for Students in Tertiary Institution. *J. Appl. Sci. Environ. Manage*, 27(6), 1135–1139.
<https://doi.org/10.4314/jasem.v27i6.11>
- Omotesho, K. F., Akinrinde, F. A., Adenike, A. J. and Awoyemi, A. O. (2019). Analysis of the use of Information Communication Technologies in fish farming in Kwara state , Nigeria. *Journal of Agribusiness and Rural Development*. 4(54), 327–334.
<https://doi.org/10.17306/J.JARD.2019.01223>
- Onyeacholem, J. I. and Omede, U. E. (2023). *Authenticated and Dynamic Websites : A Sure Control against Website Spoofing Attacks*. 9(3), 57–60.
www.questjournals.org
- Oyibo, A. A. (2021). Technical Efficiency of Catfish Farming In Delta North Agricultural Zone Of Delta State , Nigeria. *Nigerian Society for Animal Production (NSAP) 46th Annual Conference*, 9, 1291–1294.
- Rowan, N. J. (2023). The role of digital technologies in supporting and improving fishery and aquaculture across the supply chain – Quo Vadis ? *Aquaculture and Fisheries*, 8(4), 365–374.
<https://doi.org/10.1016/j.aaf.2022.06.003>
- Vaught, T. (2024, February). Fish farming technology the Future of fish farming : Embracing Precision Aquaculture. *AQUA Sightline*, November 2024, 46–49. <https://www.sightline.com>
- Zhang, H., and Gui, F. (2023). The Application and Research of New Digital Technology in Marine Aquaculture. *Journal of Marine Science and Engineering*, 11(2), 401.
<https://doi.org/10.3390/jmse11020401>